The Central European and Russian Heat Event of July-August 2010

By

Richard H. Grumm

1. INTRODUCTION

A strong subtropical ridge persisted over central Europe during most of the months of June, July and August 2010 (Fig. 1-3). The above normal warmth began in mid-June and persisted most of the summer. The strong subtropical ridge produced record warmth over many locations in central and Eastern Europe. Finland experienced a stretch of record warmth in July. Most of Western Russia had the hottest summer in record history[1]. The heat over Russia produced many days where the high temperatures was 40C (104F) or greater.

Russia clearly had a record warm summer with Moscow averaging near +18C and +16C above normal for the month of July and August. Under the subtropical ridge 850 hPa temperatures were 2 to 4SDs above normal over Russia during the month of July (Fig. 1b). The high temperatures combined with dry conditions (Fig. 1d) created massive fires across the country. Peat bog and forecast fires made the news during the months of July and August. The country is experiencing the worse drought since 1972. The conditions may have decreased Russian grain production by about 30% relative to 2009 levels. The government put a temporary grain export limit in effect until the full impact of the heat wave on grain production is known.

Around Moscow, a record high of 37.2C[2] (98.9) was reached on 26 July 2010. This broke the previous record of 36.8C (98.2F) set back in 1920. This record fell on 29 July when the temperature peaked at 37.7C (98.9F). The airport Domodedovo hit 38C (100.4F). July 2010 was the hottest month on record for the City of Moscow. Many locations across western Russia topped 35C (95F) over the course of July and August. The heat along with the drought conditions had huge impacts on lakes, rivers, and fish production. As mentioned earlier the drought and hot weather impacted grain production and cause fires across western Russia.

August saw the subtropical ridge (Fig. 3) continue along with the heat. On 8 August Moscow set a new record of 34.7C breaking the previous record of 33.2C set back in 1932. In the first 8 days of August, Moscow set new record highs on 6 days. The high topped off at 36C on 6 August breaking the old record of 35.4C set in 1920. On 3 August they hit 34.9C (94.6F).

Previous research has shown the importance of subtropical ridges and heat waves (Chang and Wallace 1987; Galarneau et. al 2008; Kunkel et al 1996; Lipton et al. 2005; Lyon and Dole 1995). Namias (1982) showed the patterns associated with protracted heat waves (Robinson 2001) over North America. No similar or definitive studies on protracted heat waves were found for Eastern Europe or Russia. Thwaytes (1995) completed a study of Northern Hemispheric heat waves.

[1] Russian Meteorological center spokes person said "We have an 'archive' of abnormal weather situations stretching over a thousand years. It is possible to say there was nothing similar to this on the territory of Russia during the last one thousand years in regard to the heat"

[2] Later reports showed thte National Exhibition center reached 37.5 on 26 July and 37.7 on 29 July conflicting data.

Heat waves often have significant impacts on human activities. Goklany (2008) and Changnon et al. (1996) showed that heat waves are a leading weather related cause of death. The elderly often suffer the most during heat waves. Prolonged heat waves are often associated with droughts (Chang and Wallace 1987; Lyon and Dole 1995). The news reports from July and August 2010 suggested that record drought conditions reduced Russian grain production. Furthermore, reports and satellite images of fires in Russia confirmed that this event produced similar effects.

This paper will document the large scale conditions associated with the eastern European and Russian heat wave of July-August 2010. The focus is on anomalies associated with key features. This is based on the work of Lipton and Grumm (2005) which showed the value of anomalies in identifying heat waves and warm episodes.

2. METHODS

The 500 hPa heights, 700 hPa temperatures, and other standard level fields were derived from the NCEP GFS 00-hour forecasts. The means and standard deviations used to compute the standardized anomalies were from the NCEP/NCAR data as described by Hart and Grumm (2001). Anomalies were displayed in standard deviations from normal, as standardized anomalies. All data were displayed using GrADS (Doty and Kinter 1995).

The standardized anomalies are computed as:

$$SD = (F - M)/\sigma \quad (1)$$

Where **F** is the value from the reanalysis data at each grid point, **M** is the mean for the specified date and time at each grid point and σ is the value of 1 standard deviation at each grid point.

The composites were made using NCEP GFS data. For each 6-hour time period the NCEP GFS analysis was used to get the mean field and anomalies of that field. The software could compute composites over any specified period. The composites were limited to 500 hPa heights, 850 hPa temperatures, 250 hPa winds, and precipitable water. Variables believed to describe a subtropical ridge and identify a heat wave.

Daily images were also produced using GFS data. However they represent a single time. The times displayed were based on news accounts of heat records over Moscow and the Climate Prediction Center plots of departures and departures from normal (Fig. 4). Any city in western Russia would have been applicable but Moscow was chosen as it is the Capitol of Russia and the NCEP CPC has good data to use as a control for the temperatures (Fig.4).

Finally, we will show several NCEP GFS and GEFS forecasts. These data will be shown to have successfully predicted this highly anomalous event.

For brevity, times will be displayed in day and hour format such at 26/1200 UTC signifies 26 July 2010 at 1200 UTC. Daily images are focused at 1200 UTC locally as the peak temperatures in Russia were typically achieved around 1500 LST which is around 1100 UTC.

3. RESULTS

i. Composite pattern

Figures 1-3 showed the patterns for the months of June-July and August 2010. The data for August was terminated when the pattern broke. As shown in Figure 4, cooler weather moved through the region ending the protected period of abnormally warm weather.

The key features associated with the protracted heat wave included abnormally strong subtropical ridge (Fig. 1a,2a, & 3a). During July the 500 hPa height wer 1 to 2SDs above normal over western Russia (Fig. 2a) with a 5820 m contour over the region during the entire month. This strong ridge displayed the subtropical jet well north of its summer postion. The 250 hPa winds showed a strong and anomalous jet (Fig. 2a) during July over Scandinavia.

Beneath the strong ridge the 850 hPa temperatures were above normal (Figs. 1b,2b, and 3b). During July the 850 hPa temperatures (Fig. 2b) over Russia were 2 to 3 SDs above normal. These values are more commonly found in daily not monthly composite data indicating how abnormally warm July 2010 was.

The moisture surge around the western edge of the subtropical ridge is evident in all three images (Figs. 1d,2d & 3d) of composite precipitable water (PW). These data show how the flow around the ridge can transport moisture northward. On the east side of the ridge the PW was generally normal to slightly below normal for the month.

ii. Record hot days: July 26-29

Figures 5-9 show the 1200 UTC fields for 26-29 July 2010. These data were included in the July composites. Around 26/1100 UTC Moscow set a new all-time record high which is close to the time of the data in Figure 5 when 850 hPa temperatures were in the 20-22C range and were 4 to 5SDs above normal. The subtropical ridge was relative progressive from 26/1200 through 29/1200 UTC (Figs 5-9). This produced a surge of warm air ahead of what a frontal system. This surge pulled a 24C contour into southern Russia (Fig. 8b) at 28/1200 UTC and produced a small area of 5SD 850 hPa temperature anomalies. A front brought considerably cooler air over much of western Russia on 29 July (Fig. 9).

These data show the surge of high PW along the western edge of the subtropical ridge. PW anomalies of 2-3SDs above normal were present over Scandanavia. Over northern Russia, the ridge increased the gradient and the 250 hPa winds reached as high as 5SDs above normal at times over northern Russia (Fig. 5c).

iii. Record hot days: August 4-8

The first 10 days of August 2010 saw several new daily high temperature records set in Moscow (Table 1). The daily images of these days for 4-8 August are shown Figures 9-13.

The strong subtropical ridge with a closed 5880 m contour at 04/1200 UTC intensified and a high latitude 5940 m ridge was present by 06/1200 UTC and persisted through 07/1200 UTC before weakening to 5880 m at 07/1200 UTC. The changes in the ridge clearly impacted the intensity of the subtropical jet rounding the ridge.

During this period of time the 850 hPa temperatures were 22 to 24C over much of west-central Russia. This produced an expansive area of 4 to 5 SD temperature anomalies over the region. Briefly, at 08/1200 UTC a small area saw 5SD temperature anomalies.

Similar to the intense heat of July 2010, these data showed the surge of high PW air along and over the western and northern flanks of the massive subtropical ridge (Figs. 9d-13d).

4. CONCLUSIONS

A strong and persistent subtropical ridge brought a protracted period of high temperatures to Central and Eastern Europe in July 2010 (Fig. 2). Moscow recorded its warmers July on record. The subtropical ridge and heat persisted into August (Fig. 3) over Eastern Europe and Russia. There were two periods of record heat in Russia, one in late July and the other in early August.

The protracted heat event was associated with a persistent ridge over Eastern Europe. It is an interesting *question as to why this ridge was so persistent?* Was this feature related to the ENSO cycle and perhaps Madden-Julian Oscillation issues? What is clear is this feature did persist and thus produced a period of record heat and relatively dry conditions.

The total impact of this event is unclear. Initial reports suggest that the warm dry conditions over Russia produced peat and forest fires. These were immediate impacts. Longer term impacts include grain production. A similar heat event appeared to impact Soviet grain production in 1972. It would be interesting to compare this event to the 1972 Russian (Soviet Union) drought pattern.

The strength and persistence of the ridge was clearly identified by compositing data over monthly periods. The composite data for the month of July 2010 (Fig. 2) shows an exceptionally strong subtropical ridge and above normal 850 hPa temperatures. With such persistent above normal conditions it is understandable why many sites in Russia experienced the warmest July on record. The data for August showed a weaker ridge suggesting a change in the pattern limiting the warmest weather to the first half of the month (Fig. 4).

The daily data showed a close 5880 m ridge over Russia during the period of warmest weather. During the 5 days stretch of hot weather in August, a closed 5940 m high developed on 26-27 August (Fig. 12). Closed 5940 m ridges are a common feature with heat waves in the eastern United States. This ridge was clearly a highly anomalous feature and produced 500 hPa height anomalies over 3SDs above normal on 2 successive days. It interesting how the jet north of the ridge increased north and east of the ridge on 26-28 August (Figs. 11c-13c).

There is an implied atmospheric river (AR: Nieman et al 2008) in the composite for July 2010 (Fig. 2d). These data show how the flow around the ridge can transport moisture northward. These data show how the flow around the ridge can transport moisture northward. On the east side of the ridge the PW. Typically, in the United States this ring-of-fire effect often produces convective activity and enhanced rainfall on the western and northern flanks of the subtropical ridge.

Tables 2 & 3 show the top 30 highest 500 hPa heights and 850 hPa temperatures from a point located near Moscow, Russia. The 6 highest 500 hPa heights were observed in August 2010. These values also dominated the list of largest 500 hPa height anomalies. The 850 hPa temperatures shows a similar pattern with July and August dominating the highest 850 hPa temperature data. The largest 850 hPa temperatures anomaly was observed at 0600 UTC 5 August 2010. These data suggest that July and August 2010 were exceptionally warm months relative to all other months from 1948-2010.

Getting good weather data to explain or understand an event is difficult. News stories often contain conflicts and possibly errors. Clearly well time and geographically stamped data is essential at getting at the best ground truth. This was a difficult task to accomplish.

Finally, this record event raises many questions. Over time, the impacts on human activities will become clearer. Then there issues as to whether this was a unique situation related to a pattern which favored blocking in the summer or was it related to global warming.

5. ACKNOWLEGEMENTS

The Climate Prediction Center (CPC) for access to images of eastern European sites and specifically to David Miskus for daily data for Moscow from 1 July – 28 August 2010 used in the tables and identify the days of most intense heat over Moscow.

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Decade average (°C)		Day-to-day average temperatures (°C)										
July, 1 to 10	+18°	+17.3	+17.4	+17.5	+17.5	+17.6	+17.6	+17.7	+17.7	+17.8	+17.8	-
July, 11 to 20	+18°	+17.9	+17.9	+18.0	+18.0	+18.0	+18.0	+18.1	+18.1	+18.1	+18.1	-
July, 21 to 31	+18°	+18.1	+18.0	+18.0	+18.0	+18.0	+17.9	+17.9	+17.8	+17.8	+17.7	+17.7

http://meteo.infospace.ru/climate/html/index.ssi

T, °C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly average	-10	-9	-4	+4	+12	+16	+18	+16	+10	+4	-2	-8
Day to day variations	-10..-9	-10..-8	-8..+0	+0..+8	+8..+14	+14..+17	+17..+18	+14..+18	+7..+13	+1..+7	-5..+1	-9..-5

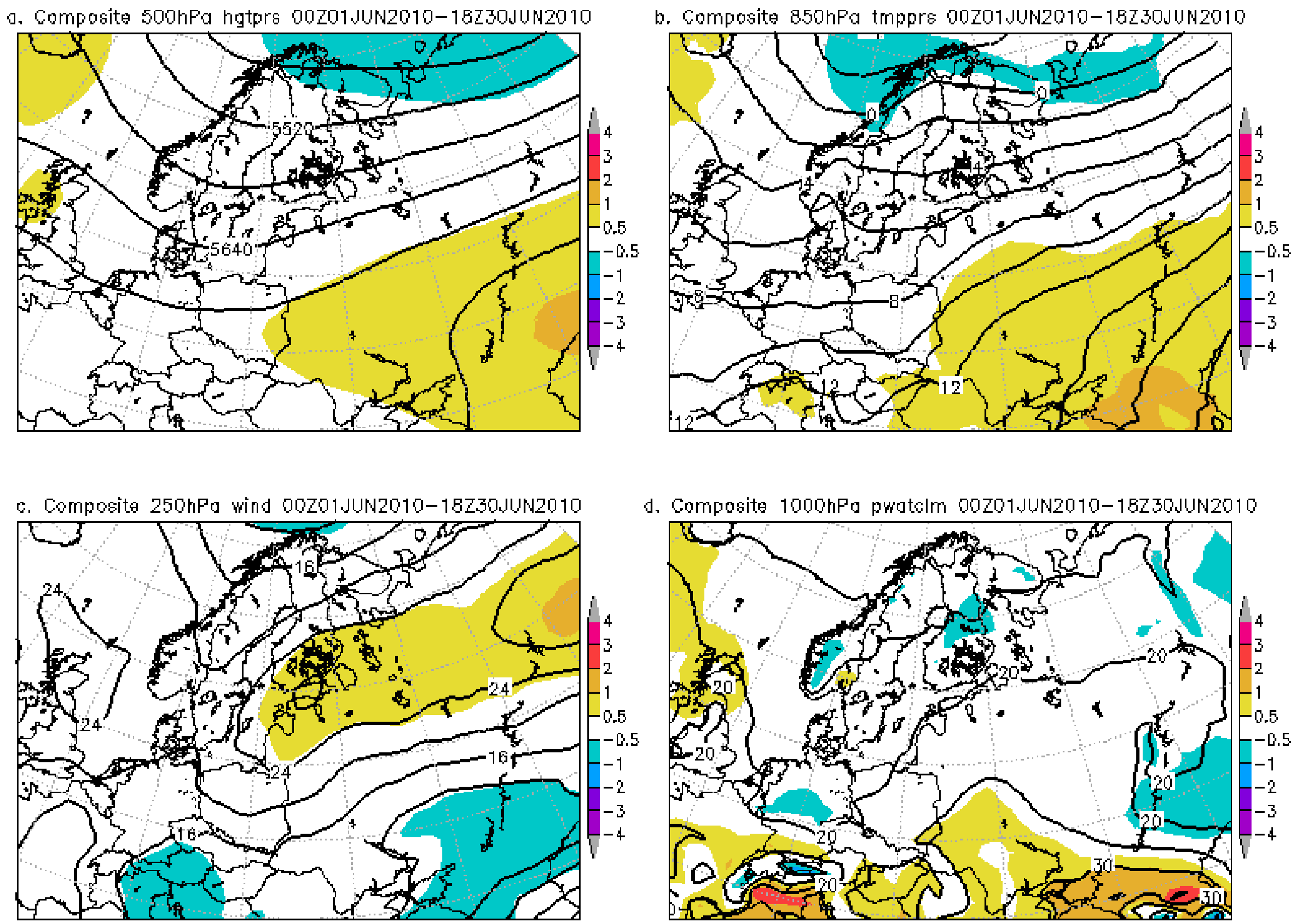

Figure 1. The mean of all GFS 00-hour forecasts from 0000 UTC 1 June 2010 to 1800 UTC 30 June 2010. Data include a) mean 500 hPa heights (m) and anomalies, b) mean 850 hPa temperatures (C) and anomalies, c) mean 250 hPa winds and anomalies, and d) mean precipitable water and anomalies. All anomalies are as in the color key to the right and are standardized anomalies in standard deviations from normal.

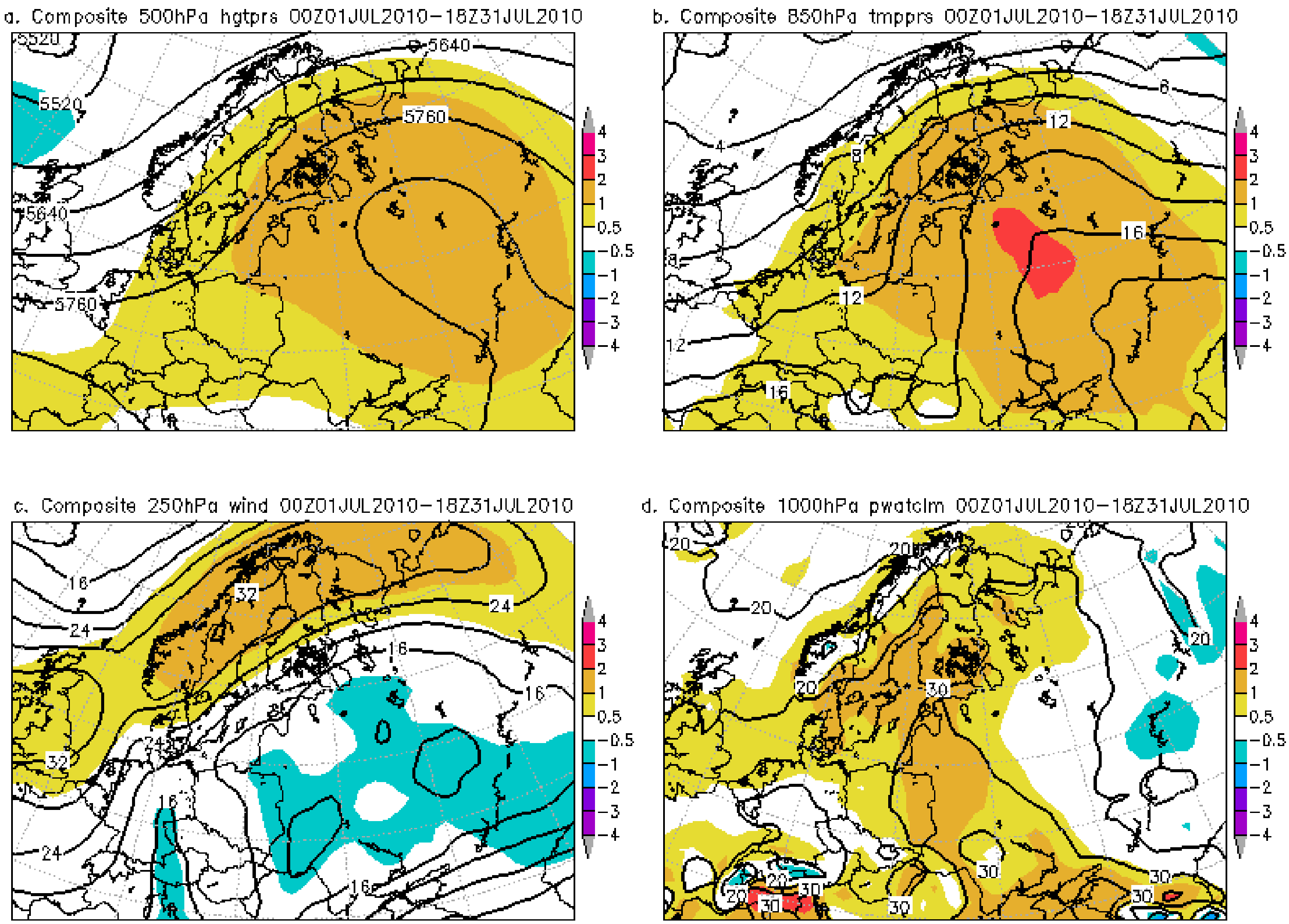

Figure 2. The mean of all GFS 00-hour forecasts from 0000 UTC 1 July 2010 to 1800 UTC 31 July 2010. Data include a) mean 500 hPa heights (m) and anomalies, b) mean 850 hPa temperatures (C) and anomalies, c) mean 250 hPa winds and anomalies, and d) mean precipitable water and anomalies. All anomalies are as in the color key to the right and are standardized anomalies in standard deviations from normal.

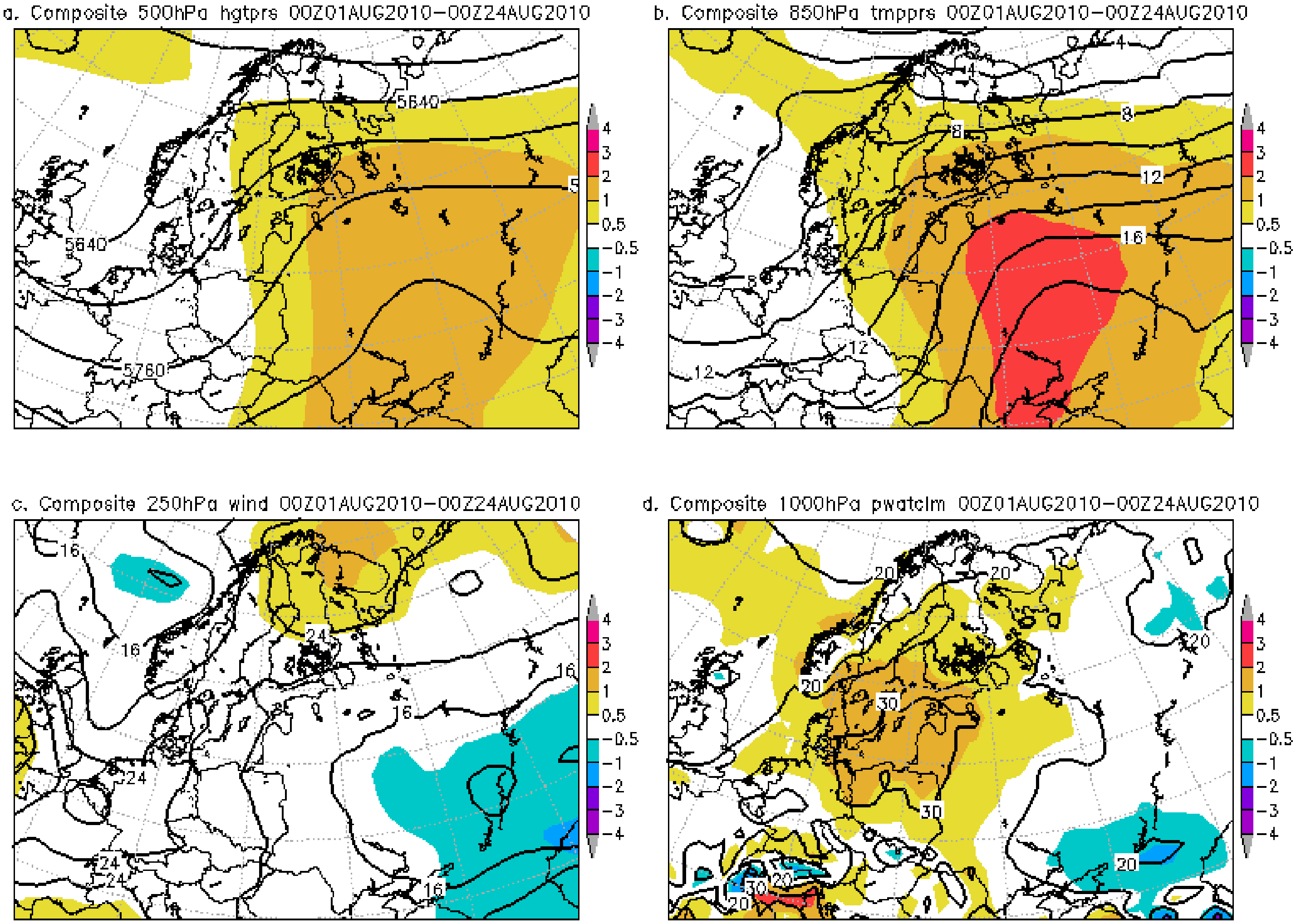

Figure 3. As in Figure 1 except for 0000 UTC 1 August through 0000 UTC 24 August 2010.

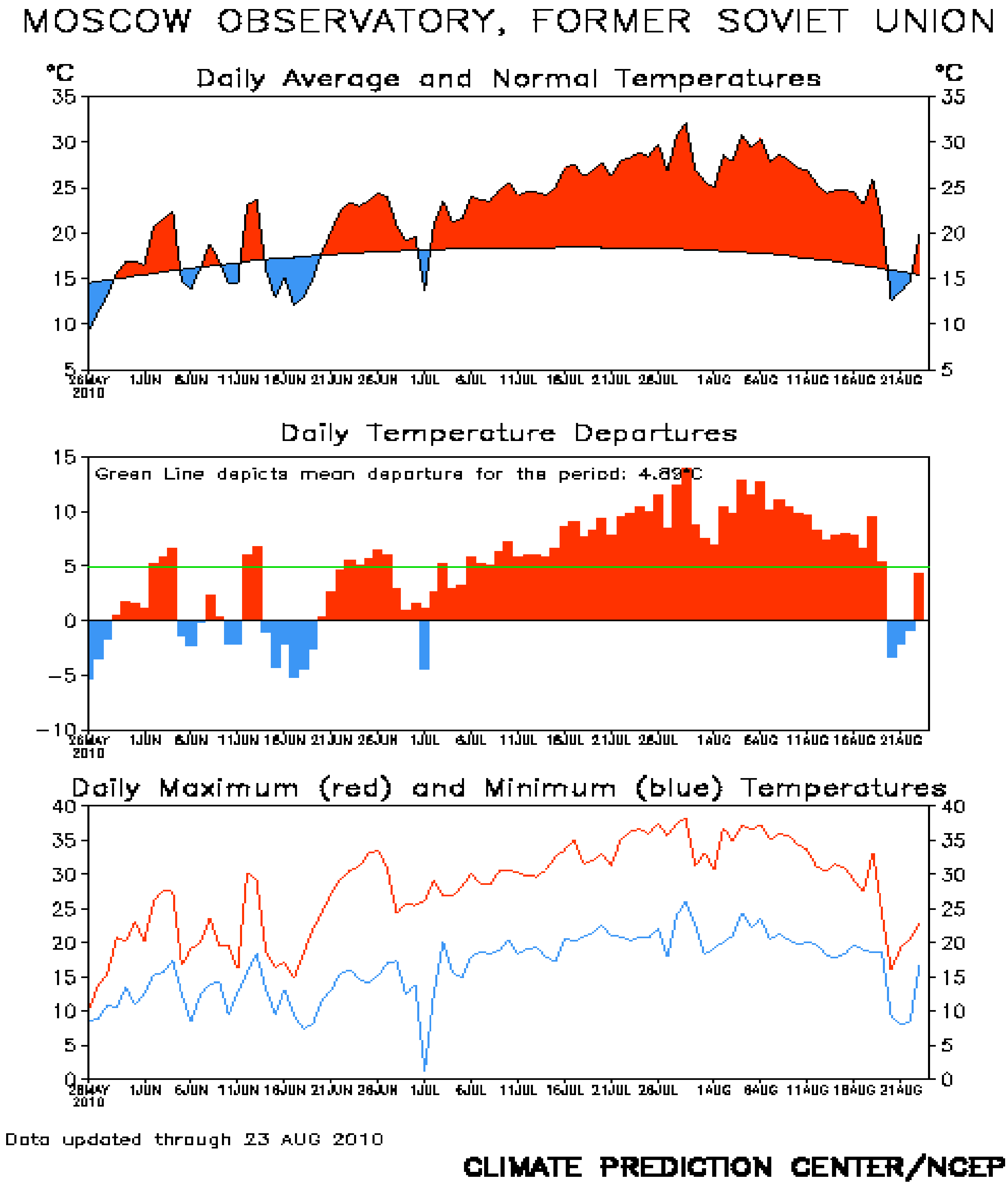

Figure 4. CPC plot of temperatures at the Moscow Observatory. Upper panel shows the daily mean verse the mean, read areas show above normal area between observed and climate. Middle images show the temperature departure (C) and low images show the daily high and low temperatures. Source NCEP Climate [Prediction Center Global Monitoring website.]

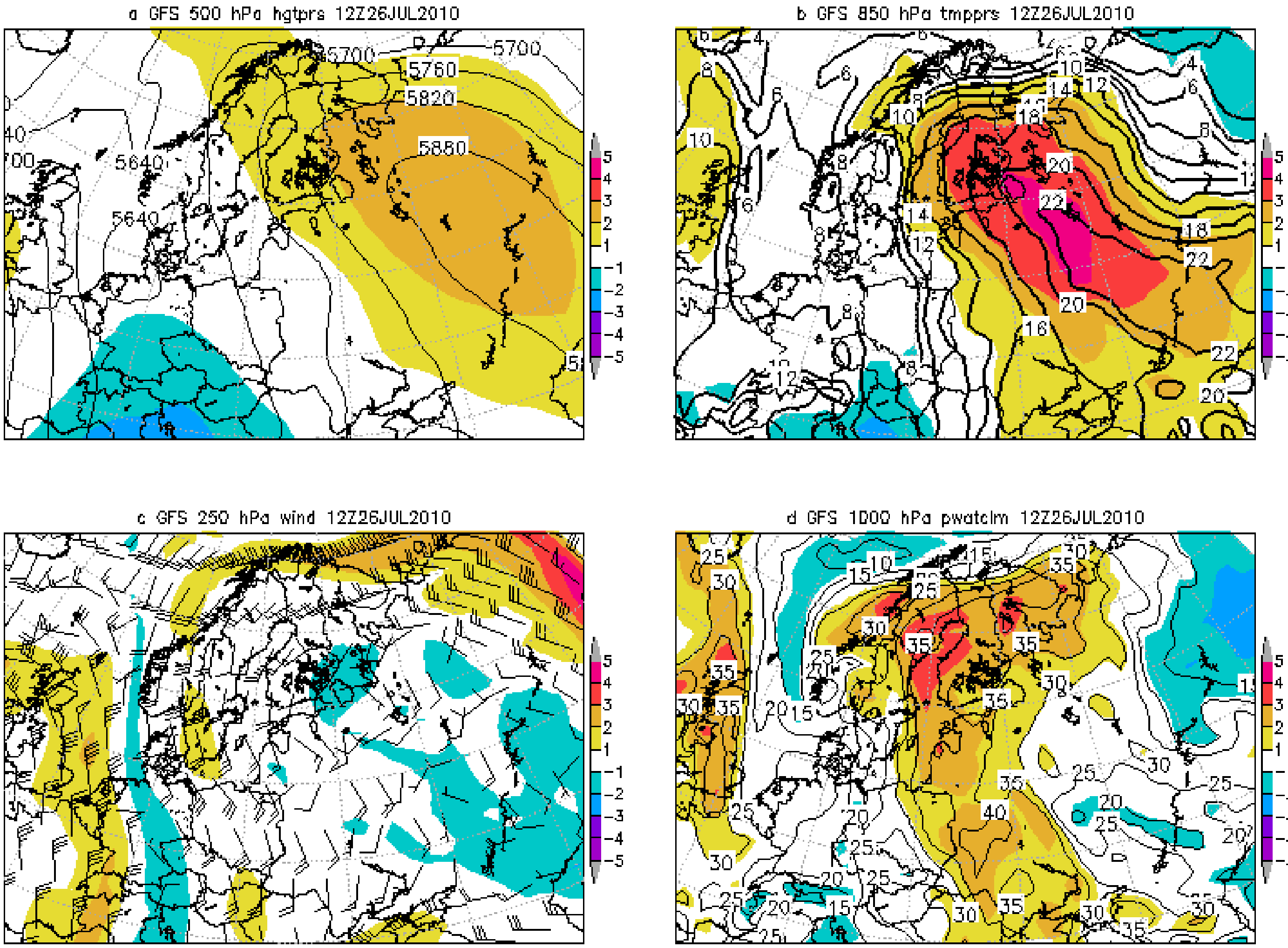

Figure 5. GFS 00-hour forecasts valid at 1200 UTC 26 July 2010 showing a) 500 hPa heights (m) and height anomaies b) 850 hPa temperatures (C) and temperature anomalies, c) 250 hPa winds (kts) and total wind anomalies, and d) precipitable water (mm) and precipitable water anomalies.

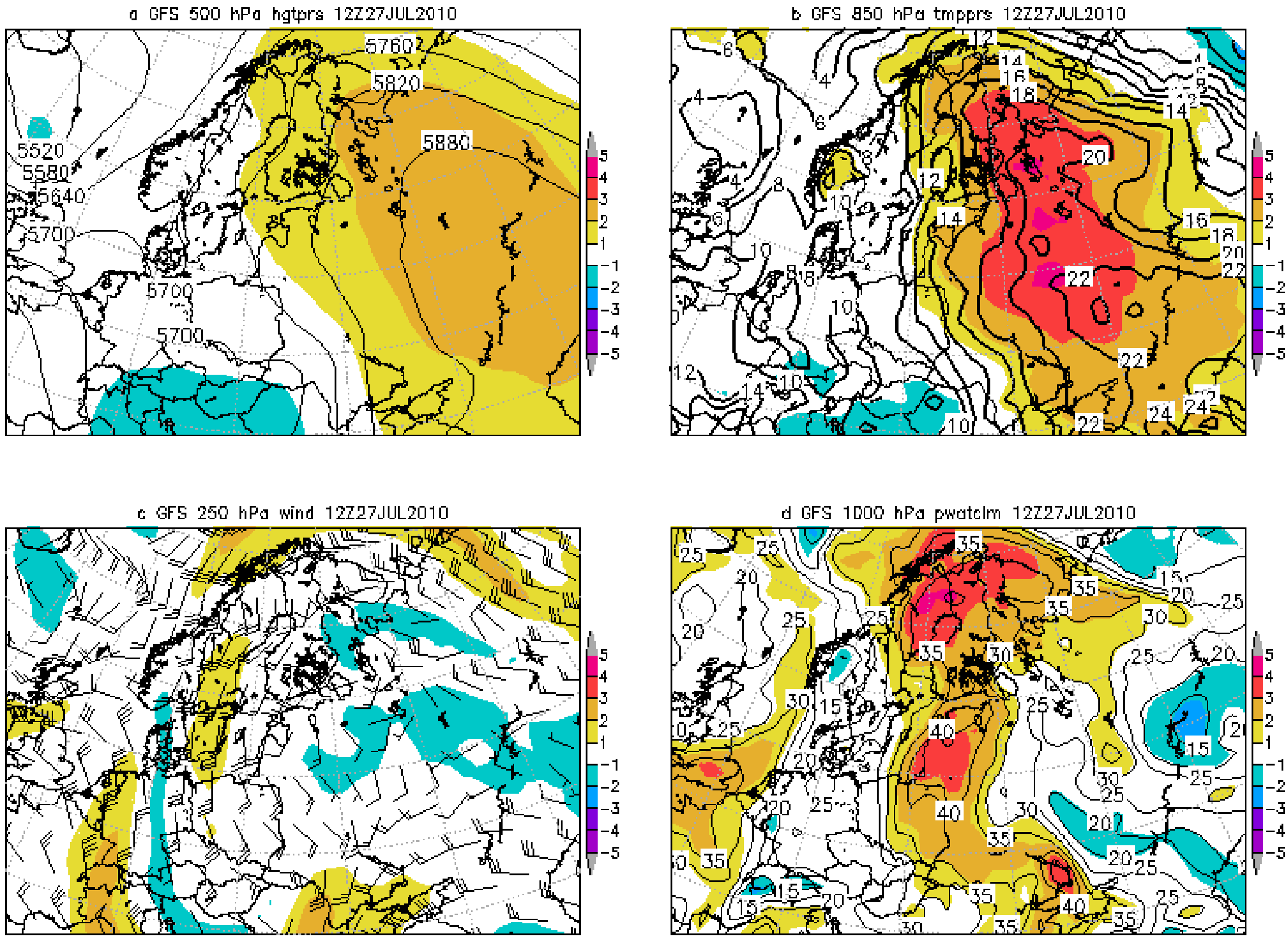

Figure 6. As in Figure 5 except valid at 27 July 2010.

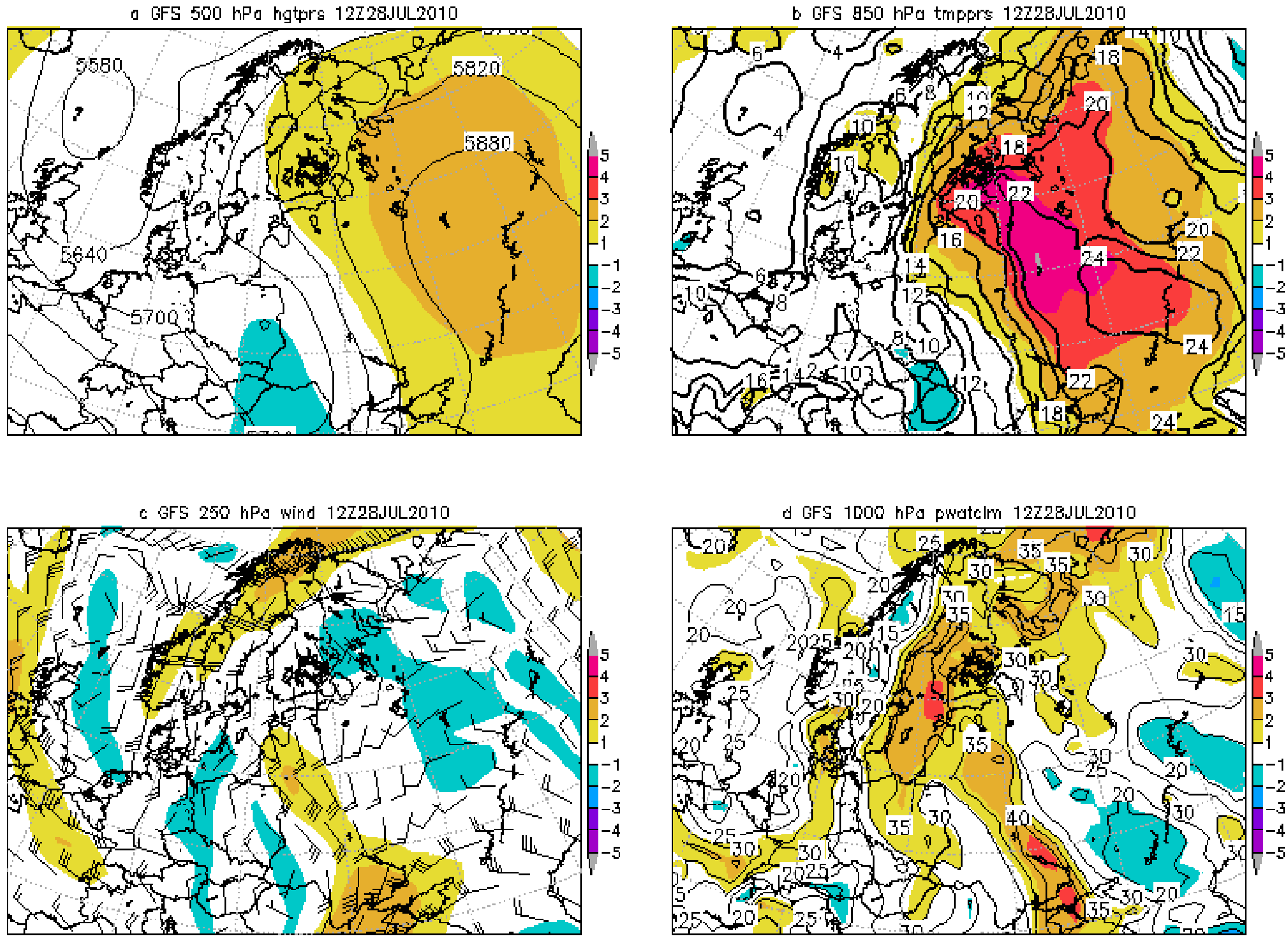

Figure 7. As in Figure 5 except valid at 28 July 2010.

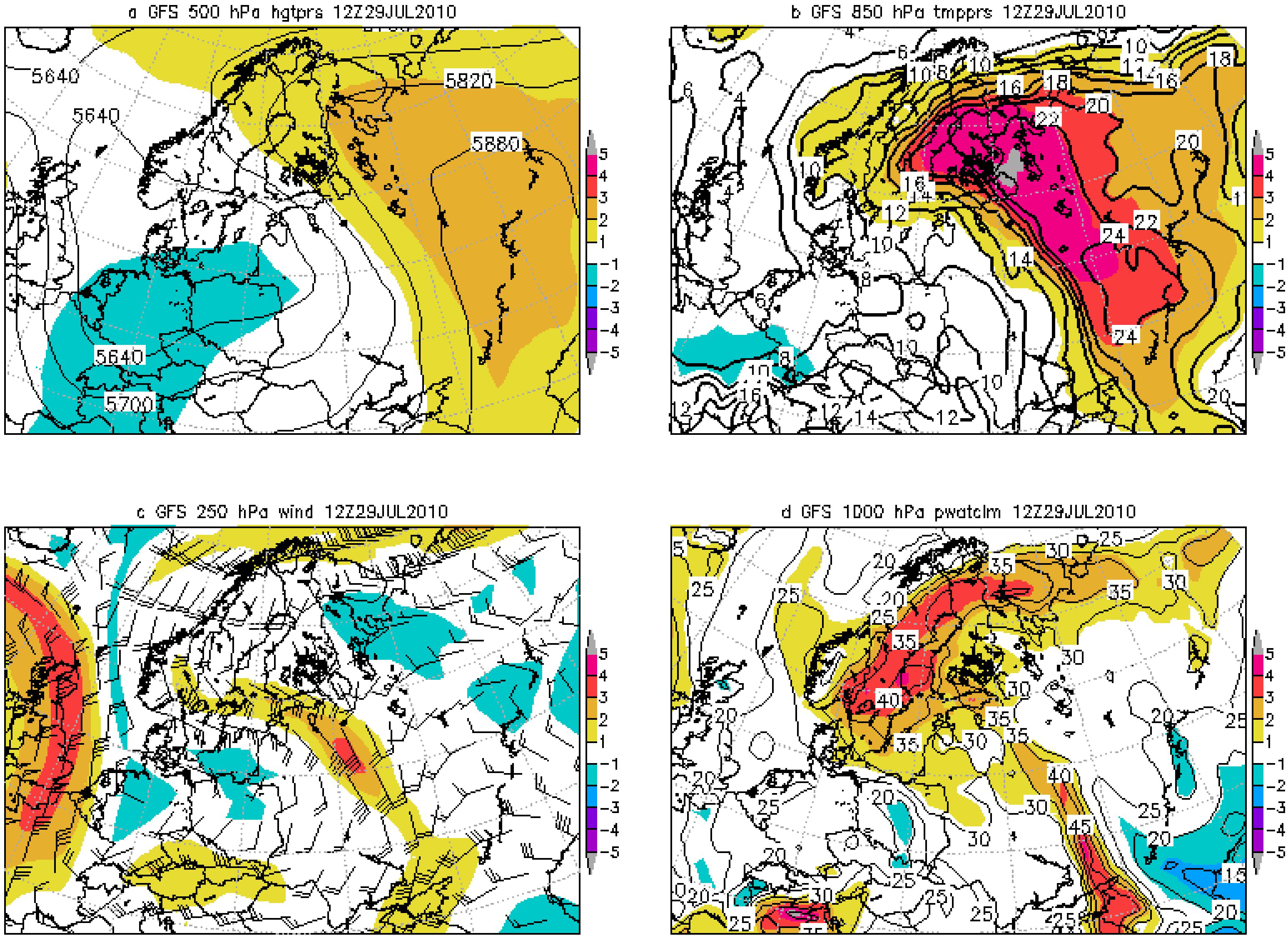

Figure 8. As in Figure 5 except valid at 29 July 2010.

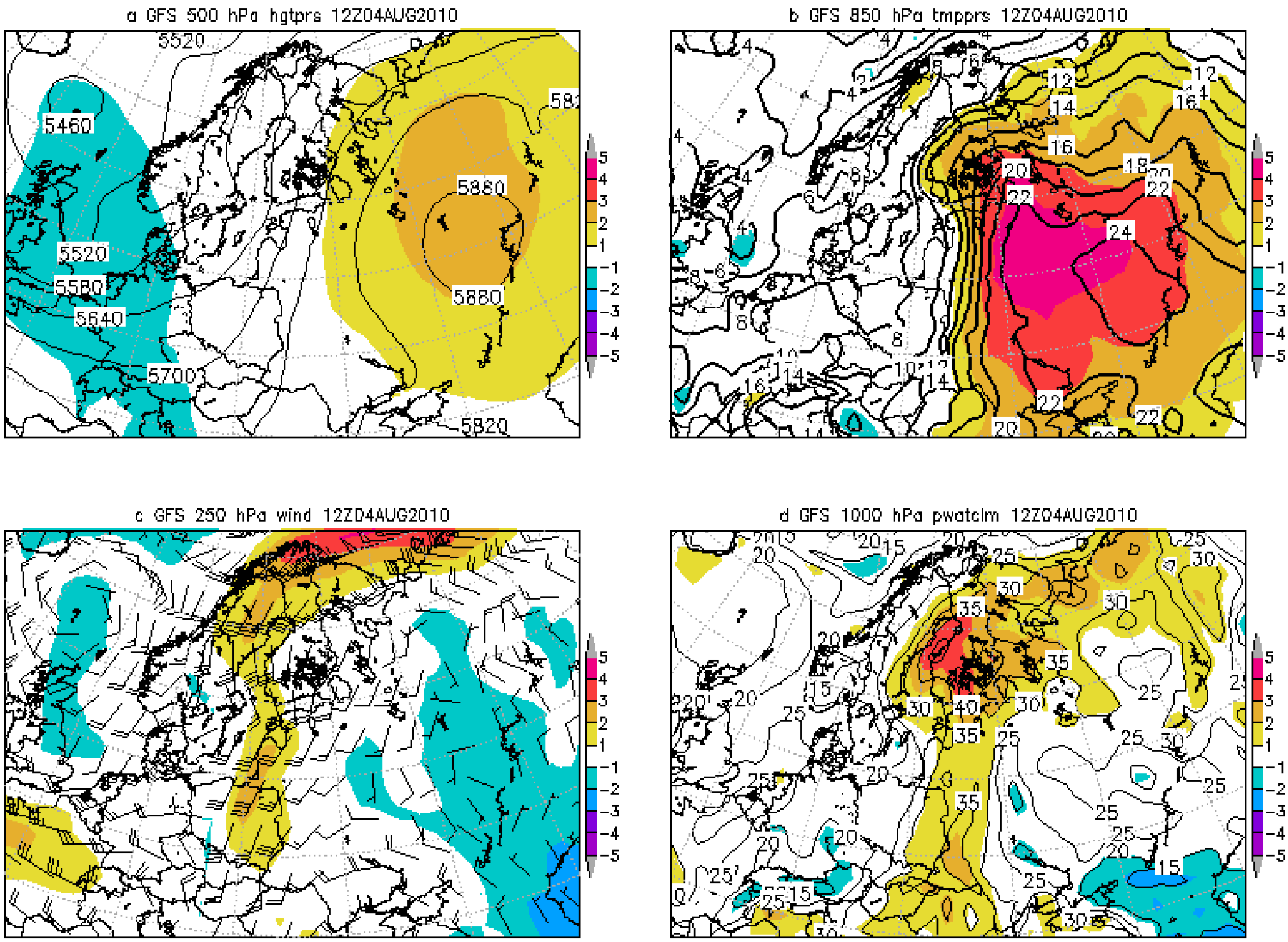

Figure 9. As in Figure 4 except valid at 1200 UTC 4 August 2010.

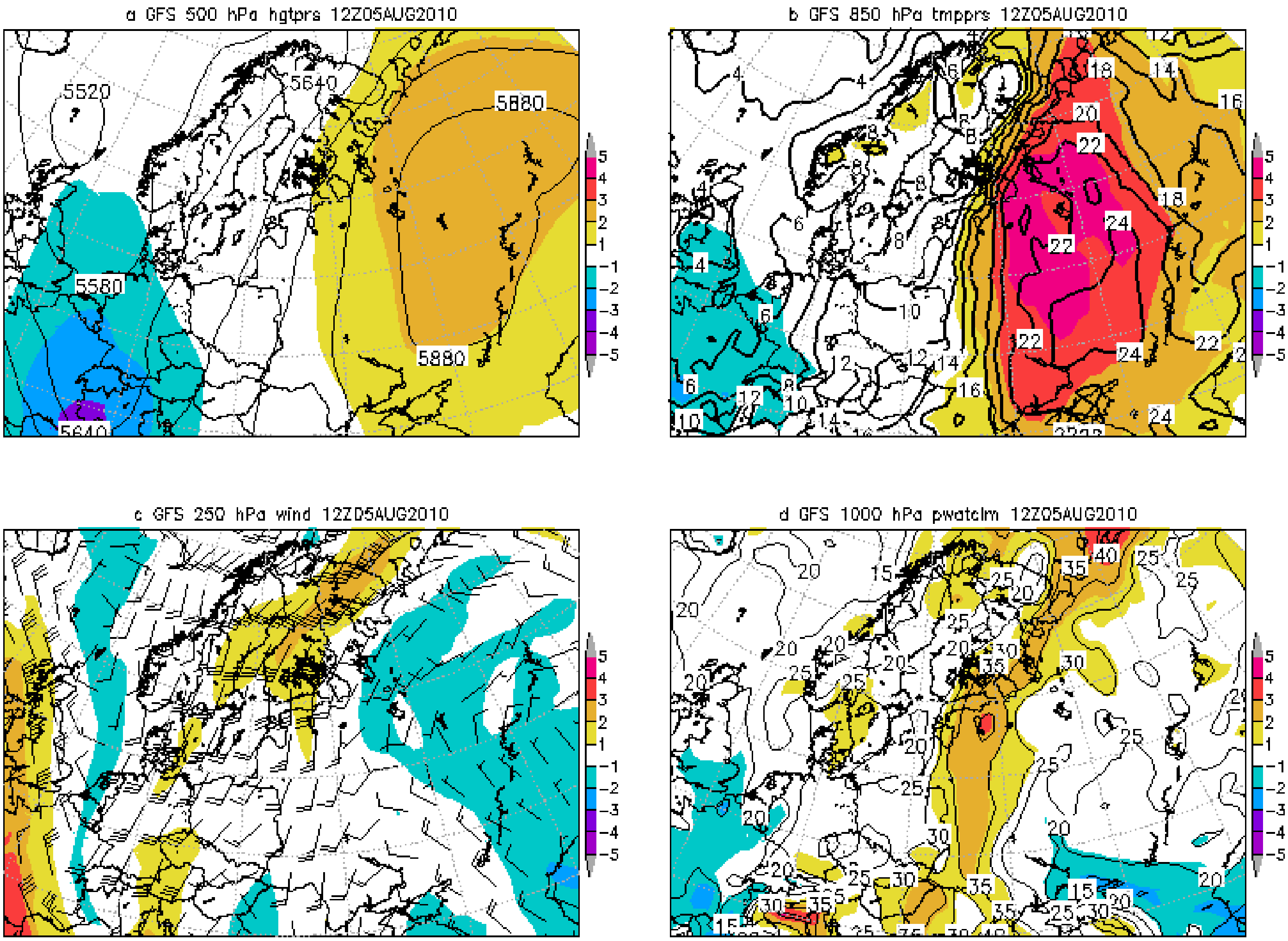

Figure 10. As in Figure 4 except valid at 1200 UTC 5 August 2010

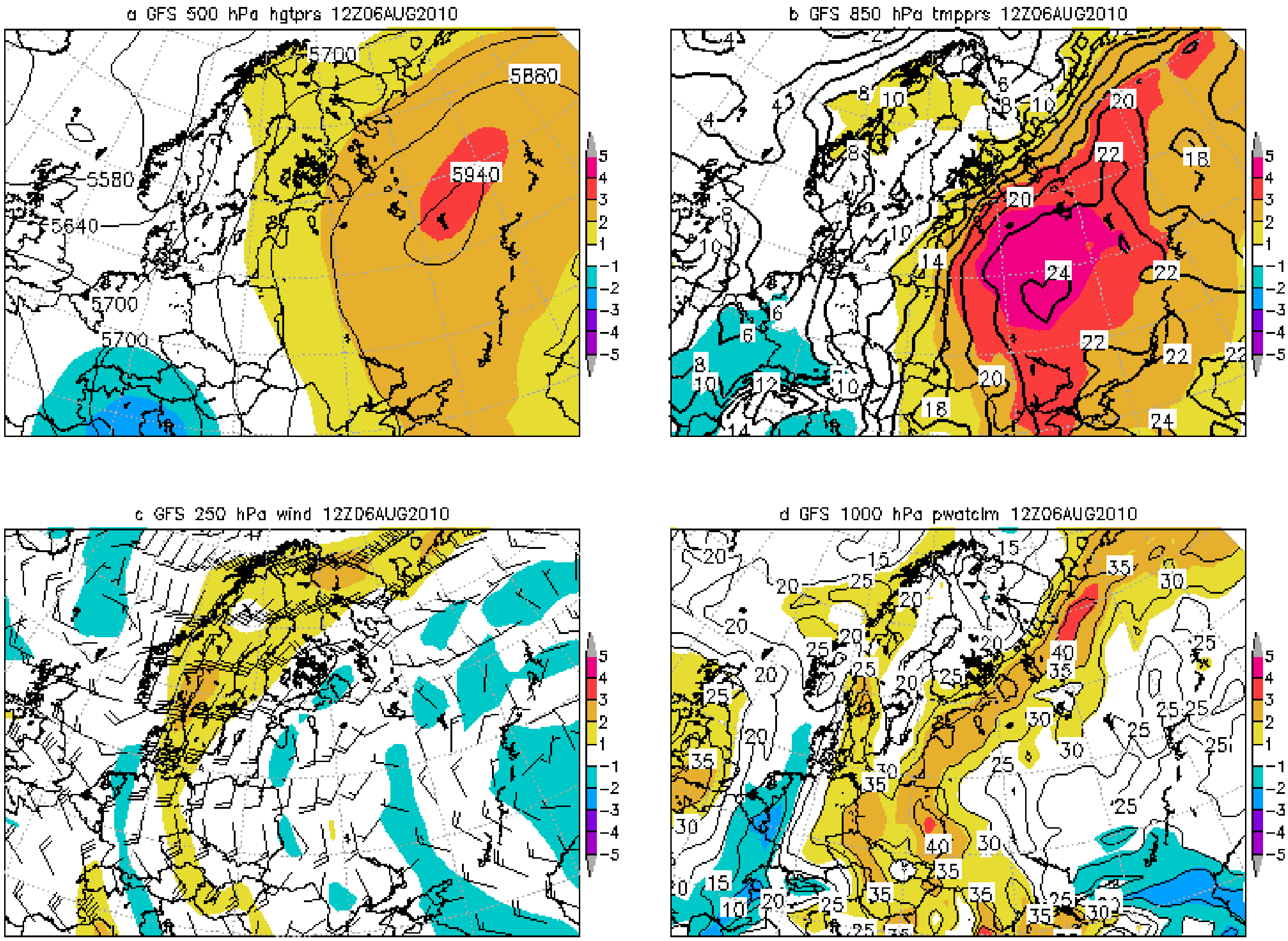

Figure 11. As in Figure 4 except valid at 1200 UTC 6 August 2010

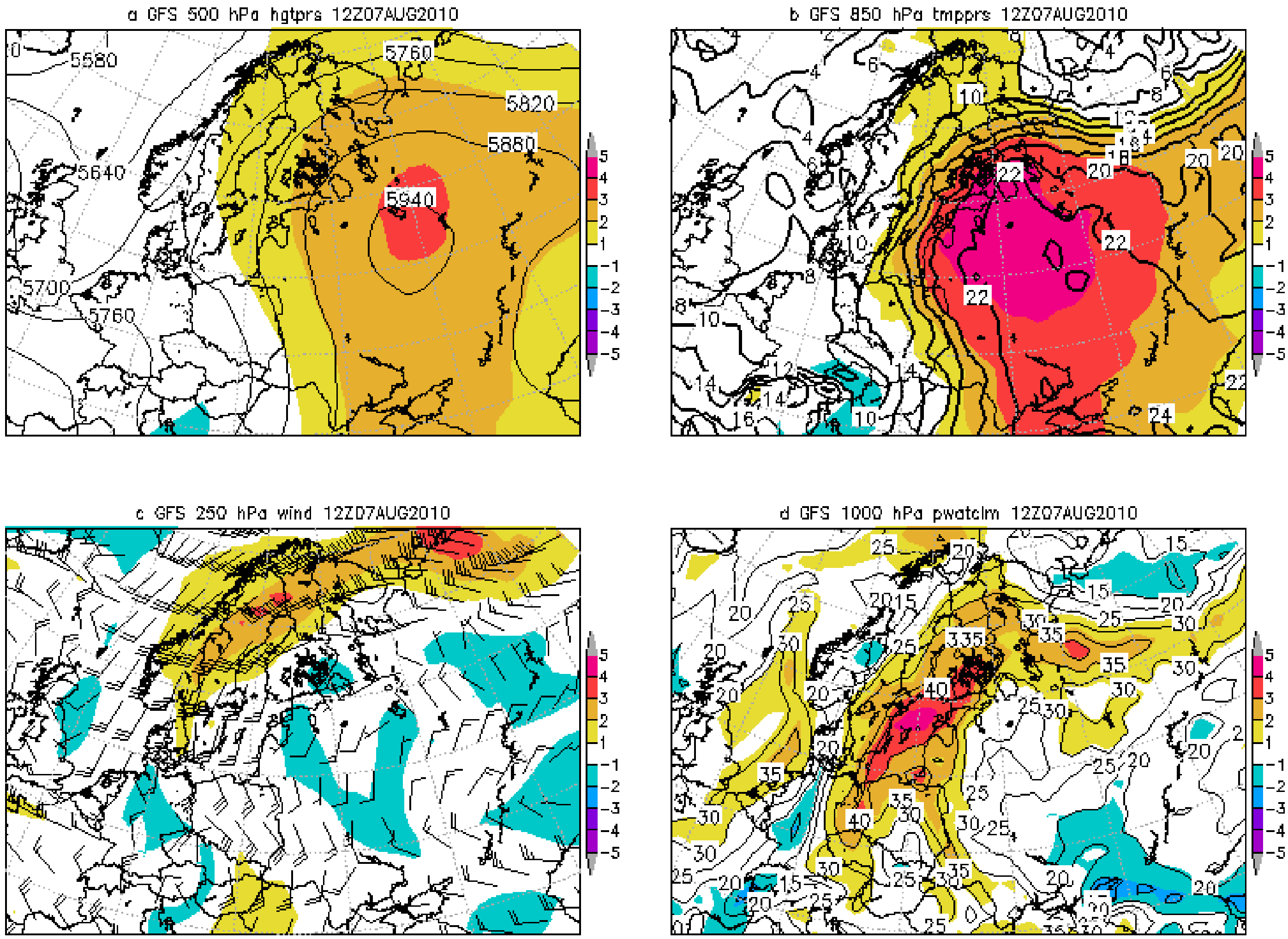

Figure 12. As in Figure 4 except valid at 1200 UTC 7 August 2010

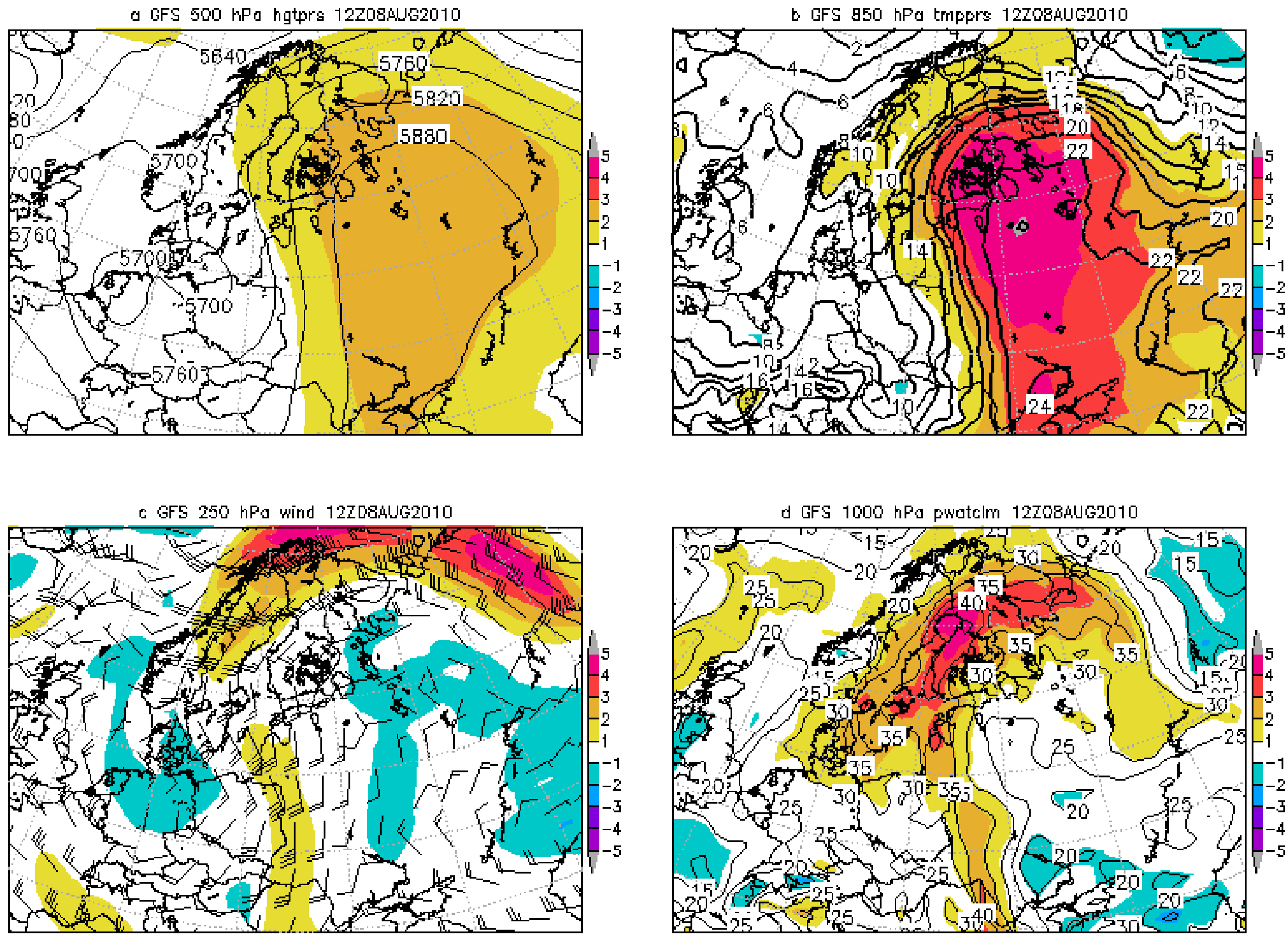

Figure 13. As in Figure 4 except valid at 1200 UTC 8 August 2010.

Moscow Observatory Data July-August 2010

Date	Max	Min	Mean	Normal	Departure	Precip(in)
20100719	90	71	81	65	16	0
20100720	91	73	82	65	17	0
20100721	88	70	79	65	14	0
20100722	95	70	83	65	18	0
20100723	97	69	83	65	18	0
20100724	98	69	84	65	19	0
20100725	97	69	83	65	18	0.03
20100726	100	72	86	65	21	0
20100727	96	64	80	65	15	0
20100728	100	75	88	65	23	0
20100729	101	79	90	65	25	0
20100730	88	73	81	65	16	0
20100731	92	65	79	65	14	0
20100801	87	67	77	65	12	0.35
20100802	98	68	83	65	18	0
20100803	95	70	83	65	18	0.01
20100804	99	76	88	64	24	0
20100805	98	72	85	64	21	0
20100806	99	74	87	64	23	0
20100807	95	69	82	64	18	0
20100808	97	70	84	64	20	0
20100809	96	69	83	64	19	0
20100810	94	67	81	64	17	0

Table 1. Daily temperature data from the Moscow Observatory. Data include date, maximum, minimum and mean temperature for the date, normal mean temperature and rainfall (in). Data was provided by the NCEP Climate Prediction Center. Shading shows daily highs above 97F and purple shows the hottest day in Moscow.

Date	Anomaly	height (m)
18Z07AUG2010	3.08	5956
18Z06AUG2010	3.07	5955
12Z07AUG2010	3.03	5954
06Z07AUG2010	3.12	5951
00Z07AUG2010	3.00	5941
12Z08AUG2010	2.88	5941
18Z14JUL1972	2.99	5940
12Z06AUG2010	2.86	5940
18Z08AUG2010	2.87	5938
12Z15JUL1972	2.91	5936
00Z08AUG2010	2.93	5935
12Z14JUL1972	2.88	5932
18Z29JUL2002	2.82	5928
00Z15JUL1972	2.89	5925
06Z15JUL1972	2.86	5925
18Z15JUL1972	2.79	5924
06Z08AUG2010	2.78	5923
06Z06AUG2010	2.78	5923
12Z29JUL2002	2.71	5921
06Z14JUL1972	2.81	5919
00Z29JUL2002	2.80	5917
00Z09AUG2010	2.67	5912
06Z29JUL2002	2.70	5911
18Z28JUL2002	2.63	5911
18Z01JUL1991	2.62	5910
18Z04SEP1999	2.54	5907
00Z06AUG2010	2.57	5906
12Z09AUG2010	2.47	5906
18Z05AUG2010	2.46	5906
18Z14AUG2010	2.39	5905

Table 2. Dates, standardized anomalies, and 500 hPa heights sorted by highest height value over a point near Moscow, Russia. Data used to make the table span the period of 0000 UTC 1 January 1948 through 24 August 2010.

Date	Anomaly	temperature (C)
18Z04AUG2010	4.88	26.05
18Z05AUG2010	4.82	25.85
06Z05AUG2010	4.99	25.25
00Z05AUG2010	4.70	24.85
18Z06AUG2010	4.50	24.75
00Z06AUG2010	4.62	24.65
06Z06AUG2010	4.74	24.45
12Z04AUG2010	4.67	24.35
00Z07AUG2010	4.49	24.25
12Z06AUG2010	4.60	24.15
18Z09AUG2010	4.25	24.15
18Z07AUG2010	4.24	24.05
18Z08AUG2010	4.14	23.85
12Z28JUL2010	4.60	23.75
00Z04AUG2010	4.34	23.75
12Z05AUG2010	4.48	23.75
00Z28JUL2010	4.41	23.55
06Z04AUG2010	4.49	23.55
06Z07AUG2010	4.45	23.55
18Z28JUL2010	4.15	23.45
00Z29JUL2010	4.32	23.45
12Z07AUG2010	4.27	23.15
06Z28JUL2010	4.44	23.05
00Z10AUG2010	4.13	23.05
06Z02AUG2010	4.18	22.95
12Z02AUG2010	4.10	22.95
18Z26JUL2010	3.95	22.85
18Z24JUL2010	3.73	22.65
18Z21JUL1981	3.52	22.55
00Z08AUG2010	3.96	22.55

Table 3. As in Table 2 except for 850 hPa temperatures (C) and temperature anomalies.

http://www.cpc.noaa.gov/products/global_monitoring/temperature/scan-nwrus_90temp.shtml